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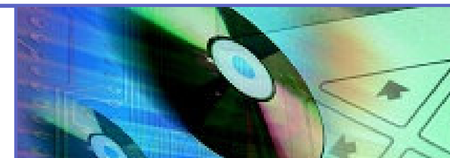
IEC 61850



IEC 61850 – Introduction

- Introduction
- Objectives of the standard
- Details of the standard
- Engineering 61850 station
- Migration and conformance tests
- Conclusions

What is IEC 61850 ??

- **IEC 61850 is a global standard for “Communication Networks and Systems in Substations”**
- It specifies an expandable **data model and services**
- It does not block future development of functions
  - It specifies **no protection or control functions**
- It supports free allocation of functions to devices
  - It is open for different system philosophies
- It provides the Substation Configuration description Language (SCL)
  - It supports comprehensive consistent system definition and engineering
- It uses Ethernet and TCP/IP for communication
  - Provides the broad range of features of mainstream communication
  - It is open for future new communication concepts

The IEC and the path to the IEC 61850 standard

- International Electrotechnical Commission (IEC) is global
- Publishes international standards for all electrical, electronic and related technologies.
- The IEC members are the national standardization organizations
  - i.e. not individuals nor companies.
- Experts in the technical committees represent their country
  - i.e. not themselves or their employer
- IEEE and EPRI work under a similar charter in North America

IEC and IEEE joined forces in 1999 and defined…

IEC 61850:
” COMMUNICATION NETWORKS AND SYSTEMS IN SUBSTATIONS ”

- IEC 61850 is the first really global standard in the Electric Utility field
  - Supported also in the ANSI/IEEE world
- Some 60 experts from Europe and North America have jointly developed the IEC 61850
  - Includes the UCA 2.0 as a subset
- All 14 parts of the IEC 61850 were published in 2004
- Influences other electric areas
  - Wind power plants, Hydro power, Distributed Energy Resources, …
- Implementation in progress by all major vendors

UCA and IEC – Two "standard worlds " merge

One world …
One technology …
One standard …

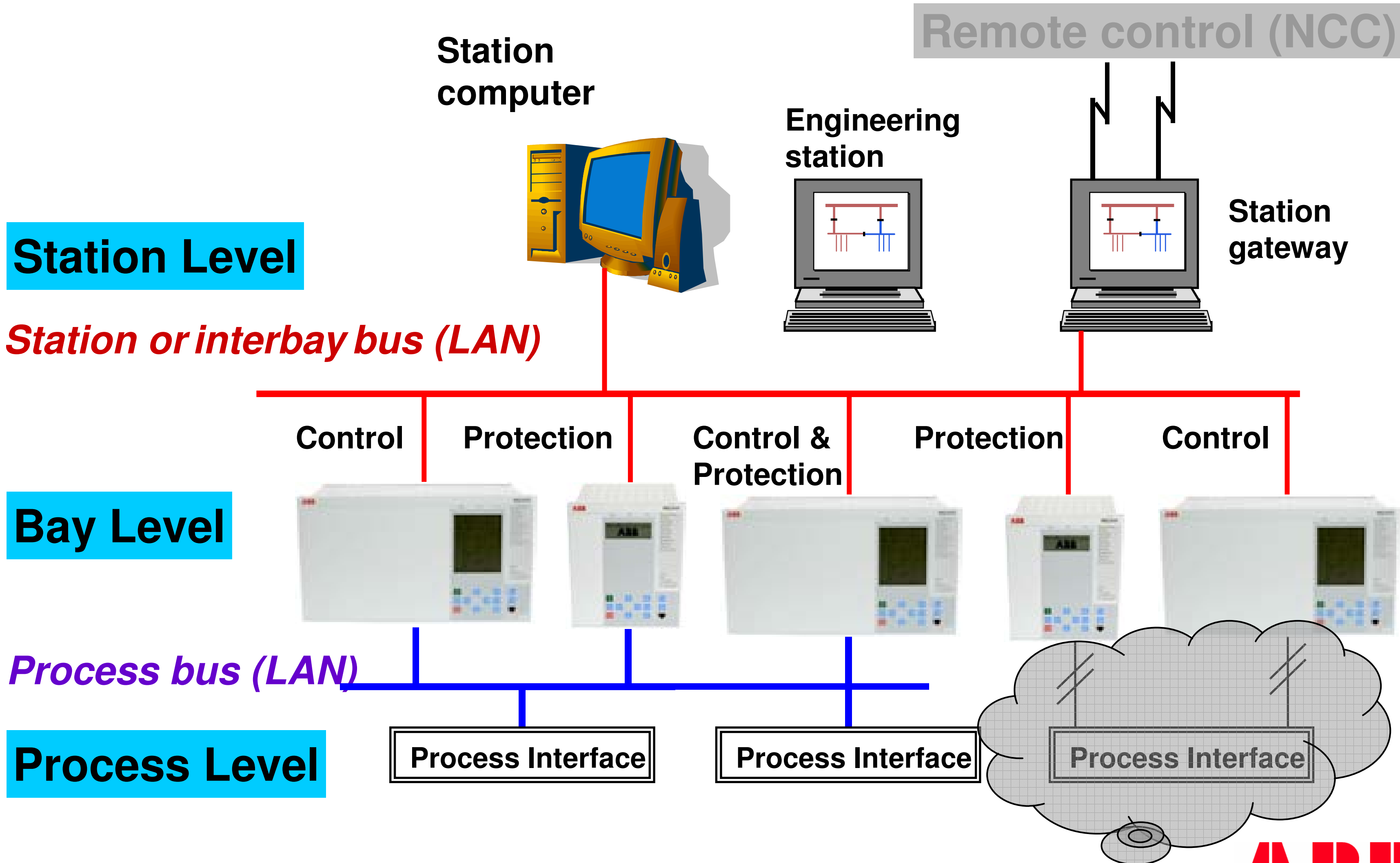
IEC 61850

… is ready now!

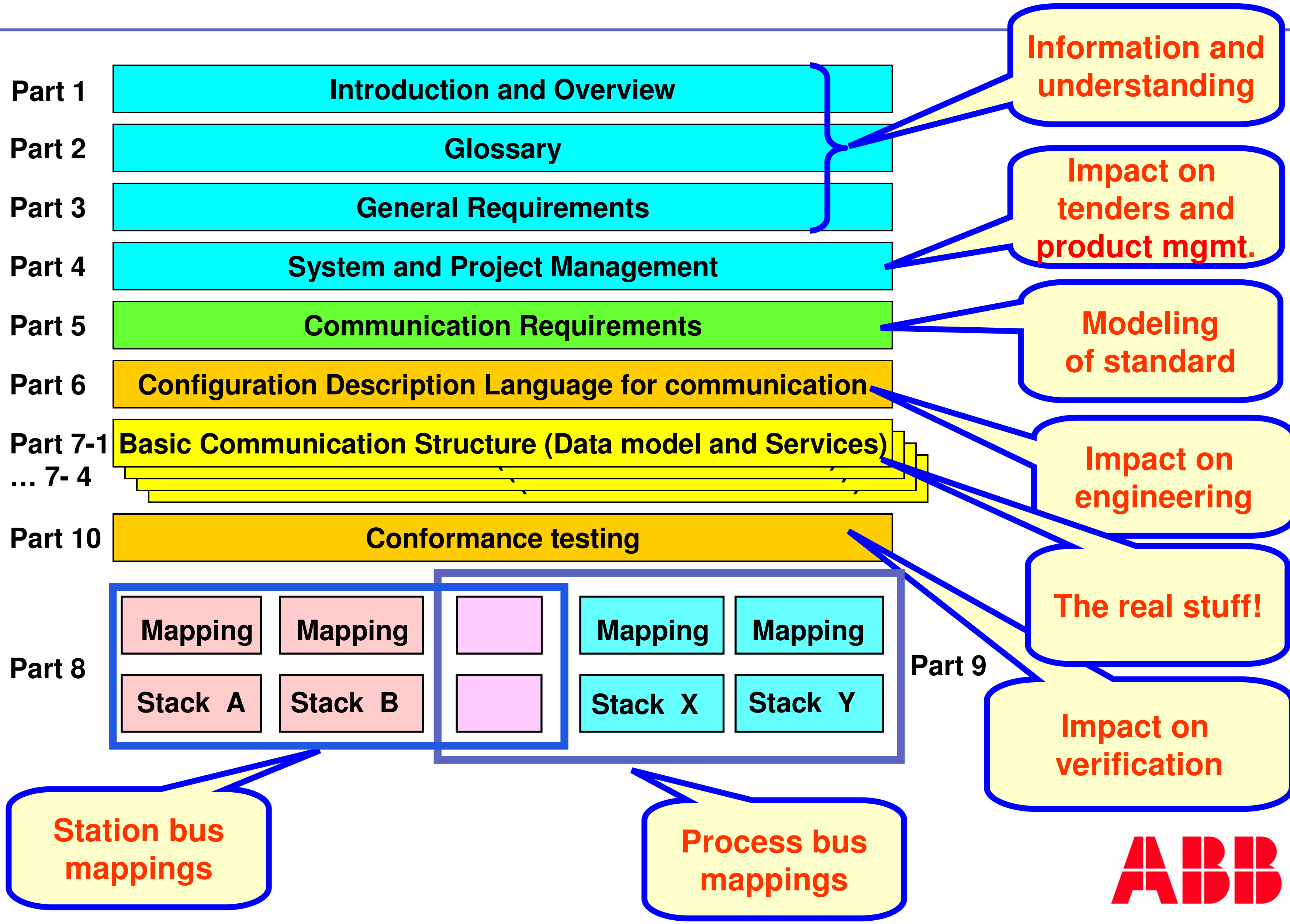
… products are in development!

… attracts a lot of attention from customers and vendors!

IEC 61850 Application Domain: Substation Automation



Structure of the IEC 61850 standard



IEC 61850 – Objectives of the standard

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Objectives for the IEC 61850 (1)

Reduce cost from cradle to grave and into next generation:

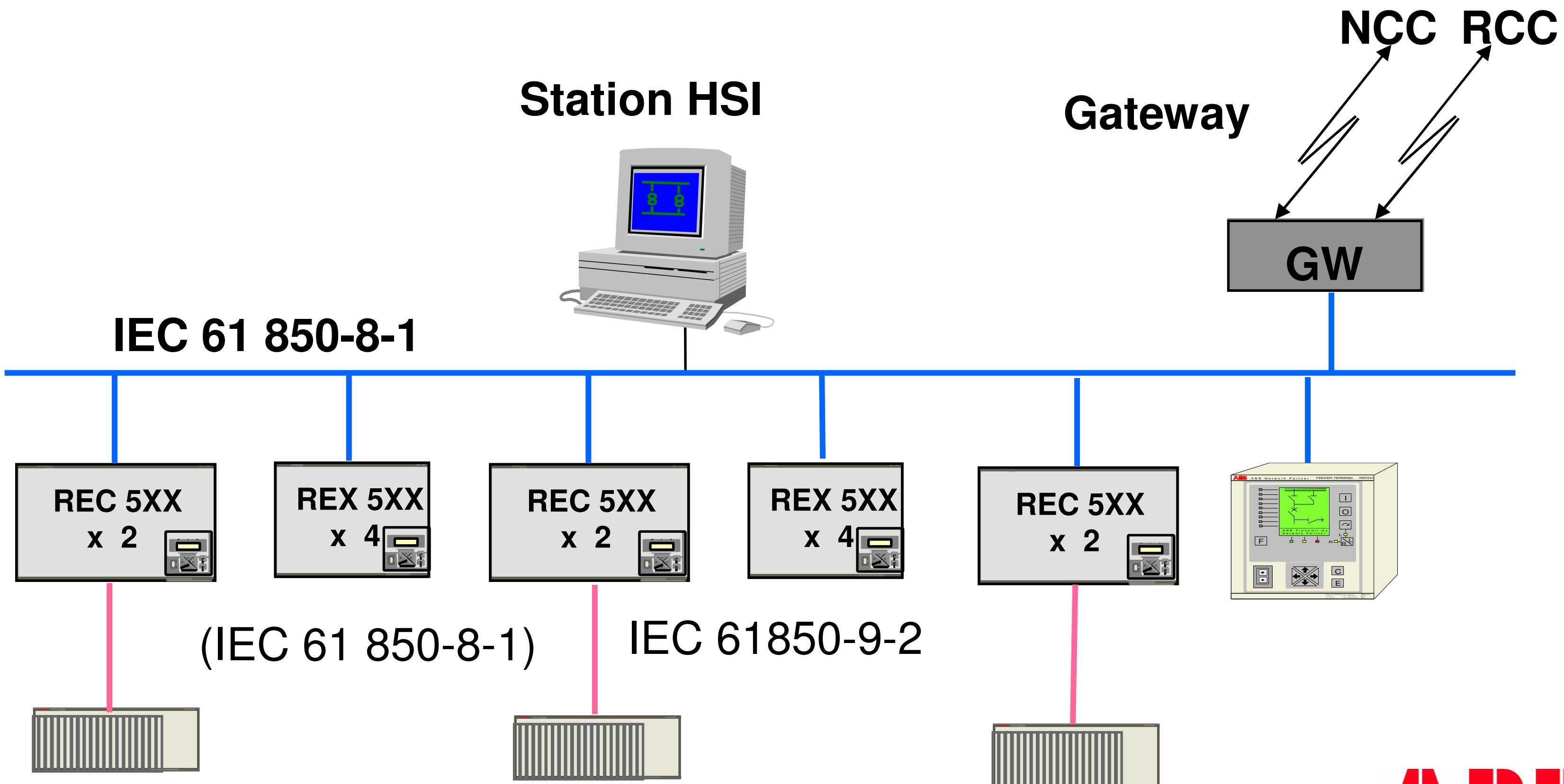
- Interoperability
  - IEDs from different vendors can **exchange and use information** over a common communications media.
    - The functionality in different devices is however not necessarily the same. Therefore **no interchangeability** of devices from different vendors!
  - Engineering and configuration data is portable between vendor tools
- Open IED description
  - Reduces the engineering and configuration
  - IEDs capabilities are described in a standardized way
  - Proprietary functions, solutions, and data are still available and allowed

Objectives for the IEC 61850 (2)

- Communication closer to Power Apparatus
  - Communication, data acquisition, and control capabilities will be directly imbedded into the primary equipment
- Free configuration
  - Free allocation of functions in centralized or decentralized system configurations.
- Reduction of conventional wiring
  - LAN instead of multiple copper wires
- Future proof
  - Utility and Vendor investments shall be long lived in spite of fast changing technology
  - The standard is able to follow the progress in communication technology as well as evolving system requirements.

Scope of IEC 61850

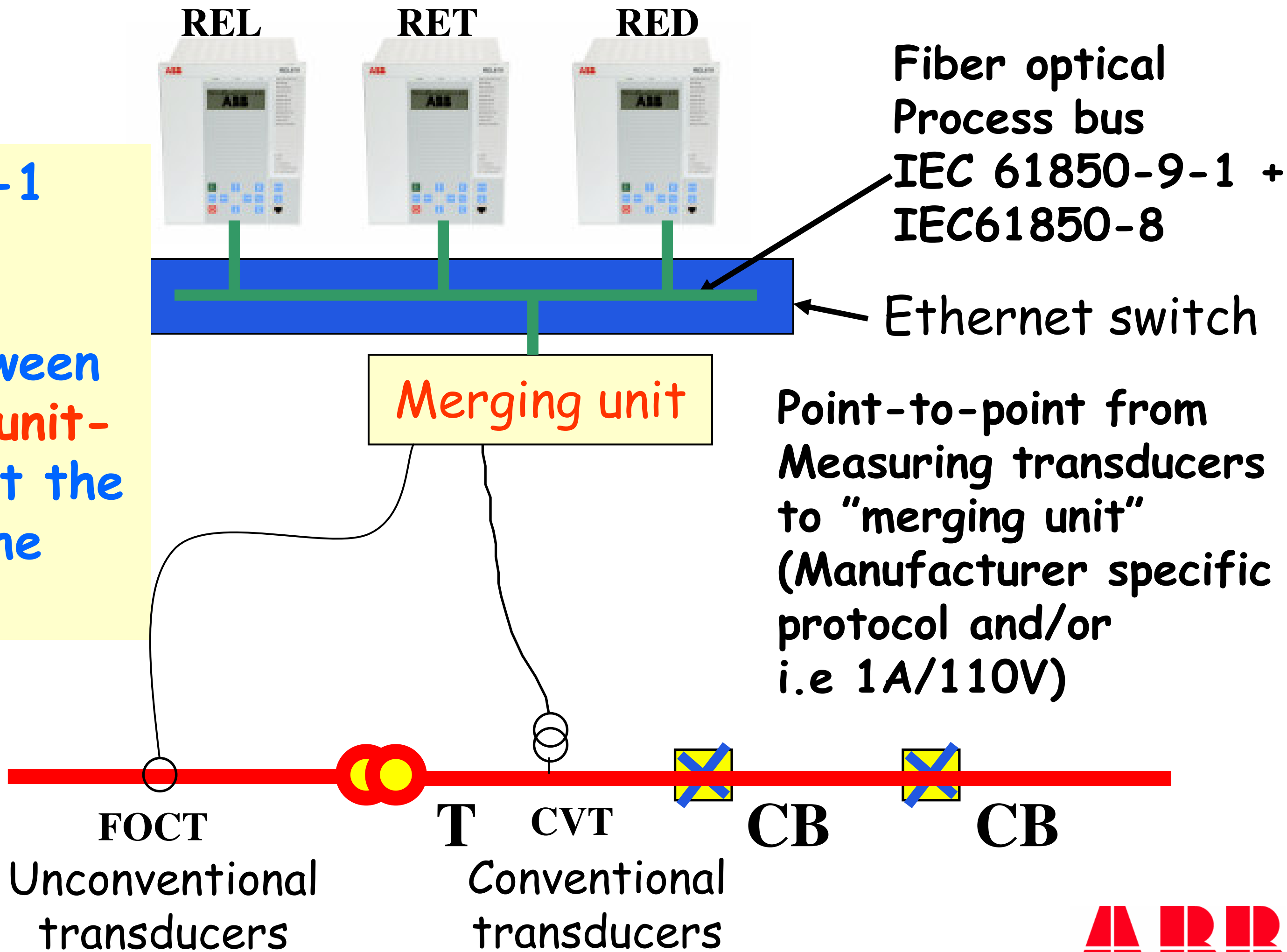
IEC 61850-8-1 is mainly a station bus for all station automation information
Is also used as process bus for medium –speed information (On the same optical fiber as IEC 61850-9-2)



Scope of IEC 61850

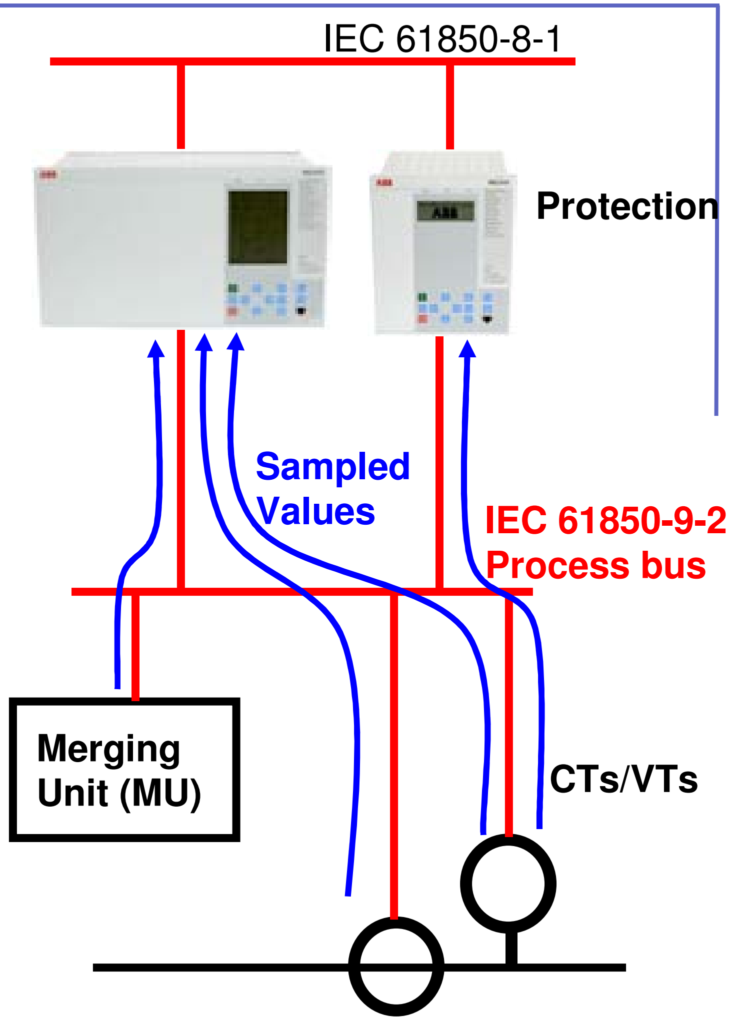
IEC 61850-9-1 fron Merging Unit to protection and control

IEC 60850-9-1 specifies the communication interface between the Merging unit-protection, not the response of the transducers.

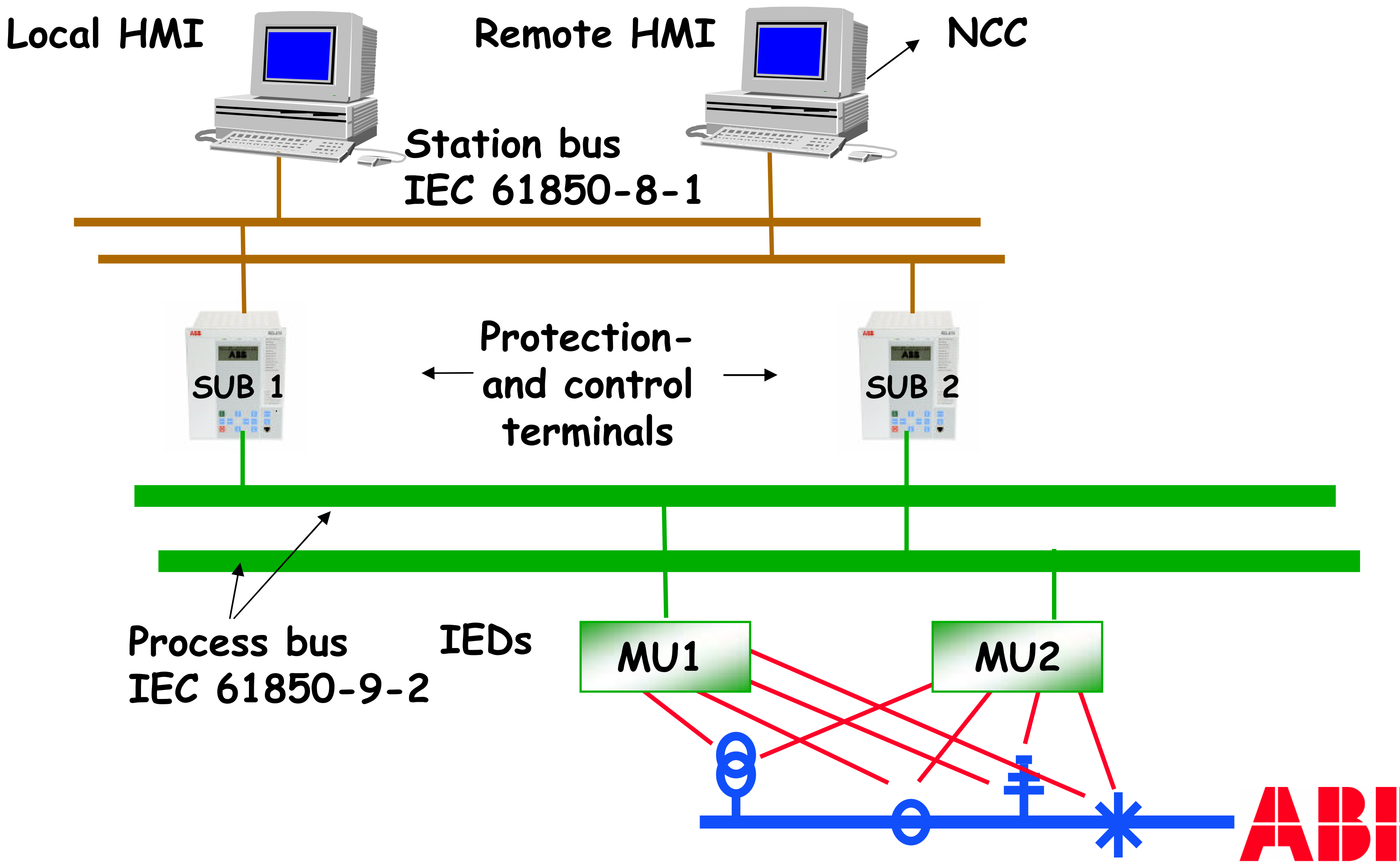


Scope of IEC 61850

- Currents and voltages are sampled and distributed to users over the process bus LAN(s)
  - One single A/D conversion
- High speed sampling
  - Up to 80 samples per period for protection (4 kHz)
  - 256 samples per period for power quality
- Sampling directly in modern CTs/VTs
- Sampling in Merging Units
  - Merging Units convert proprietary analog data acquisition to IEC 61850-9-2



Scope of IEC 61850



IEC 61850 – Details of the standard

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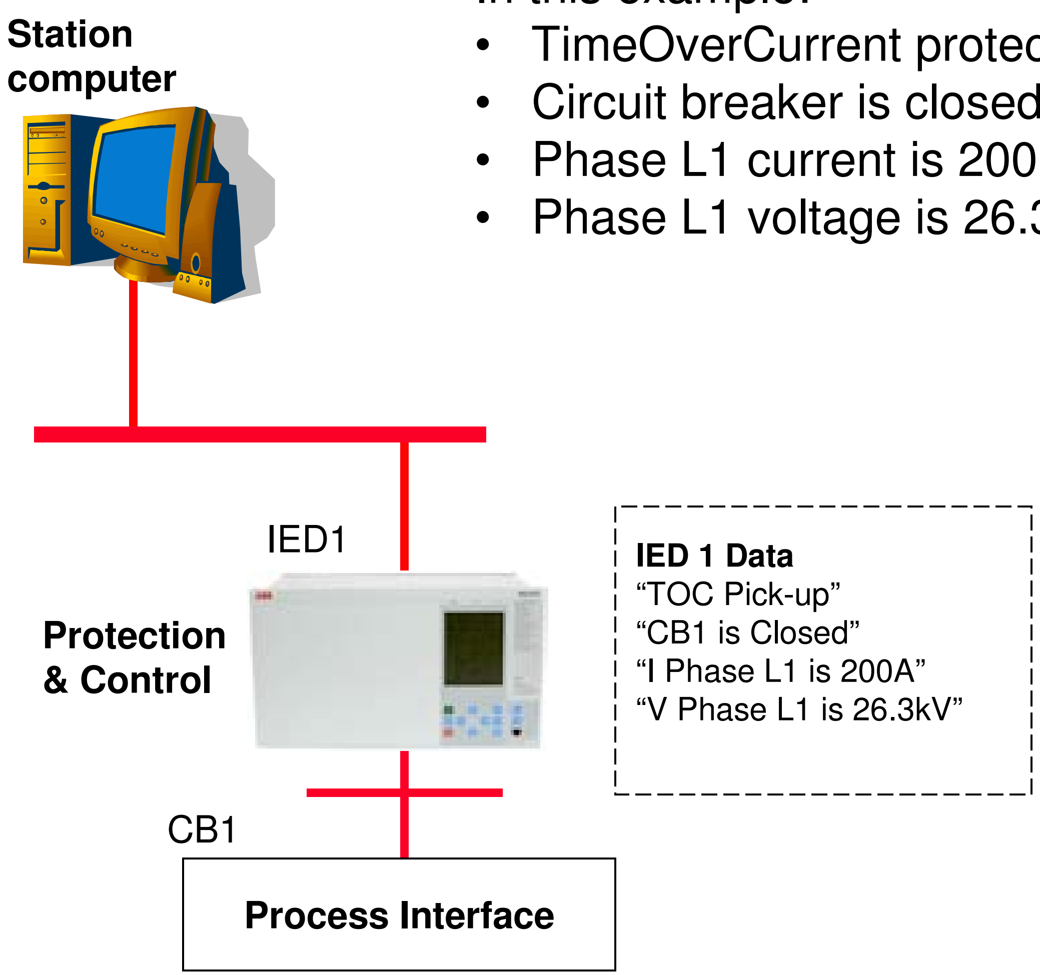
Data Communication in “Human Terms”

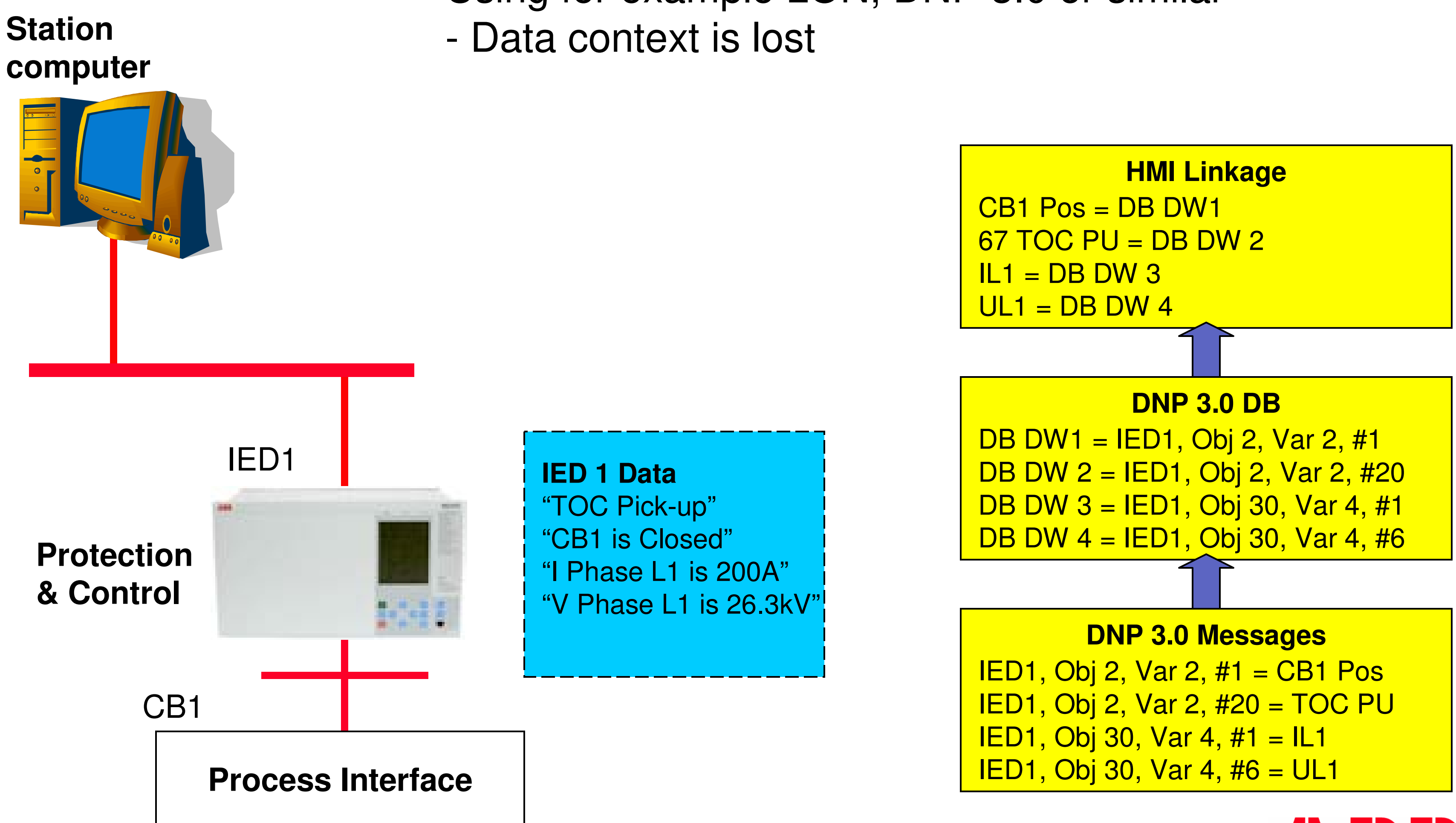
In this example:

- TimeOverCurrent protection element has picked up
- Circuit breaker is closed
- Phase L1 current is 200 A
- Phase L1 voltage is 26.3 kV



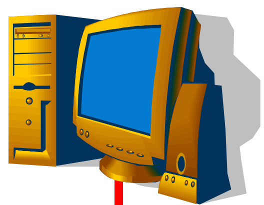
Data communication using proprietary protocols

Using for example LON, DNP 3.0 or similar
- Data context is lost



Data Communication using IEC 61850

Station computer



IEC 61850 divides data in logical groupings.
In this example:

- Protection data (the TimeOverCurrent has picked up),
- Switchgear data the CB is closed) and
- Measurement data (the values for V and I)

This IED uses data from three groupings to supervise the CB1.

IED1

Protection & Control

CB1

Process Interface

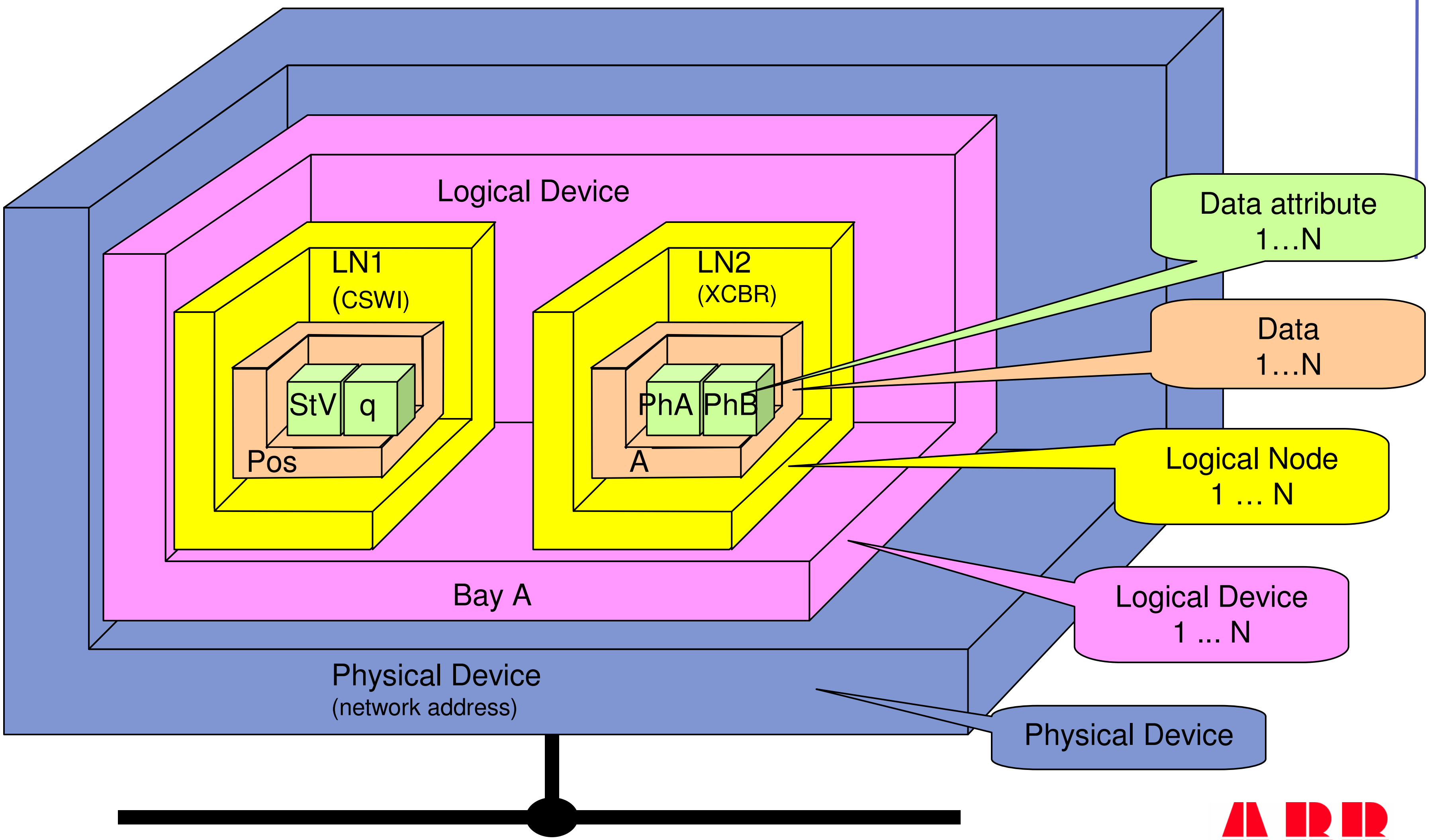
IED 1 Data
"TOC Pick-up"
"CB1 is Closed"
"I Phase L1 is 200A"
"V Phase L1 is 26.3kV"

Protection Data

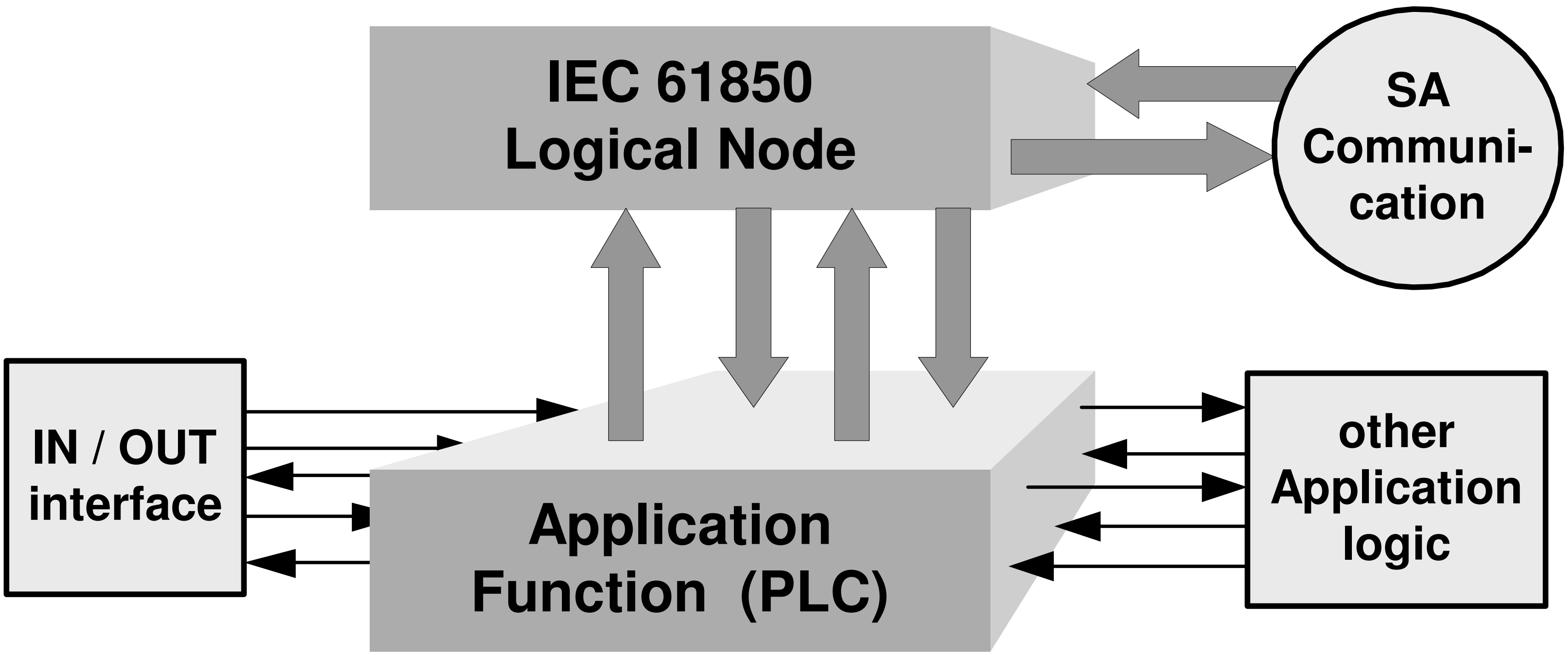
Switchgear Data

Measurement Data

Logical Groupings



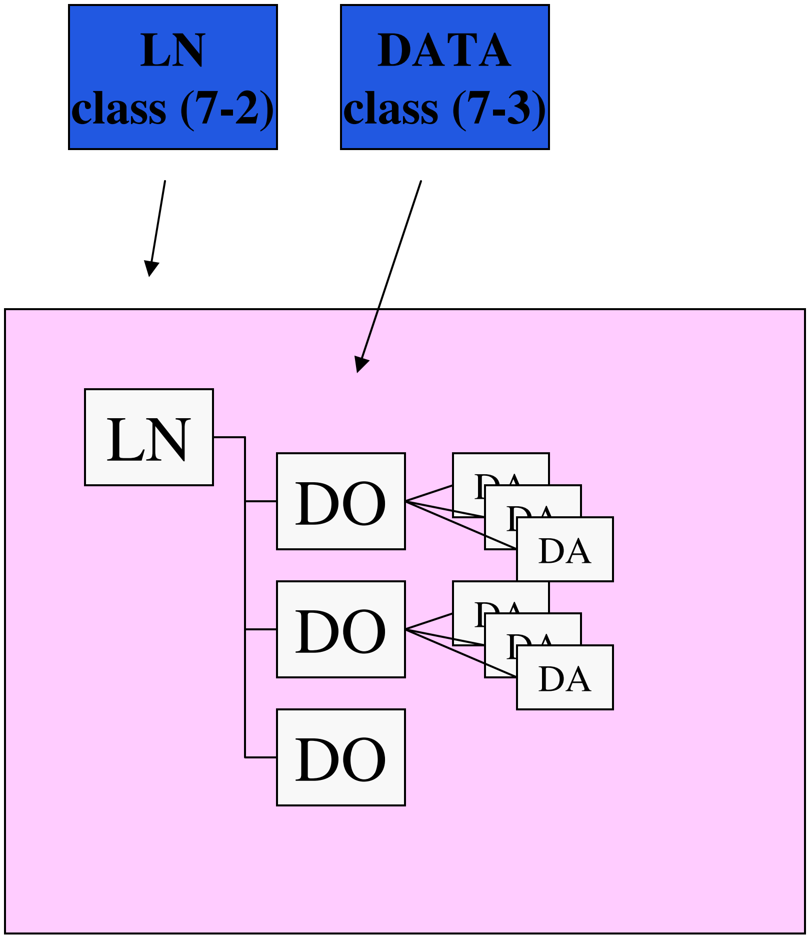
Relationship Between LN & Application Function



Logical Node

- Functions or equipment used in power systems are represented in Logical Nodes, LN
- All information and functions in a substation is structured in atomic units, the LNs
- Each LN provides a list of well organized and named information
- Complex functions use a set of LN required to represent the function
- Services enable the exchange of the information in LNs between IEDs
- Example: the LN for a Circuit Breaker has the generic name XCBR
- New logical nodes can, if required, be created according rules defined in the standard

Logical Node data structure

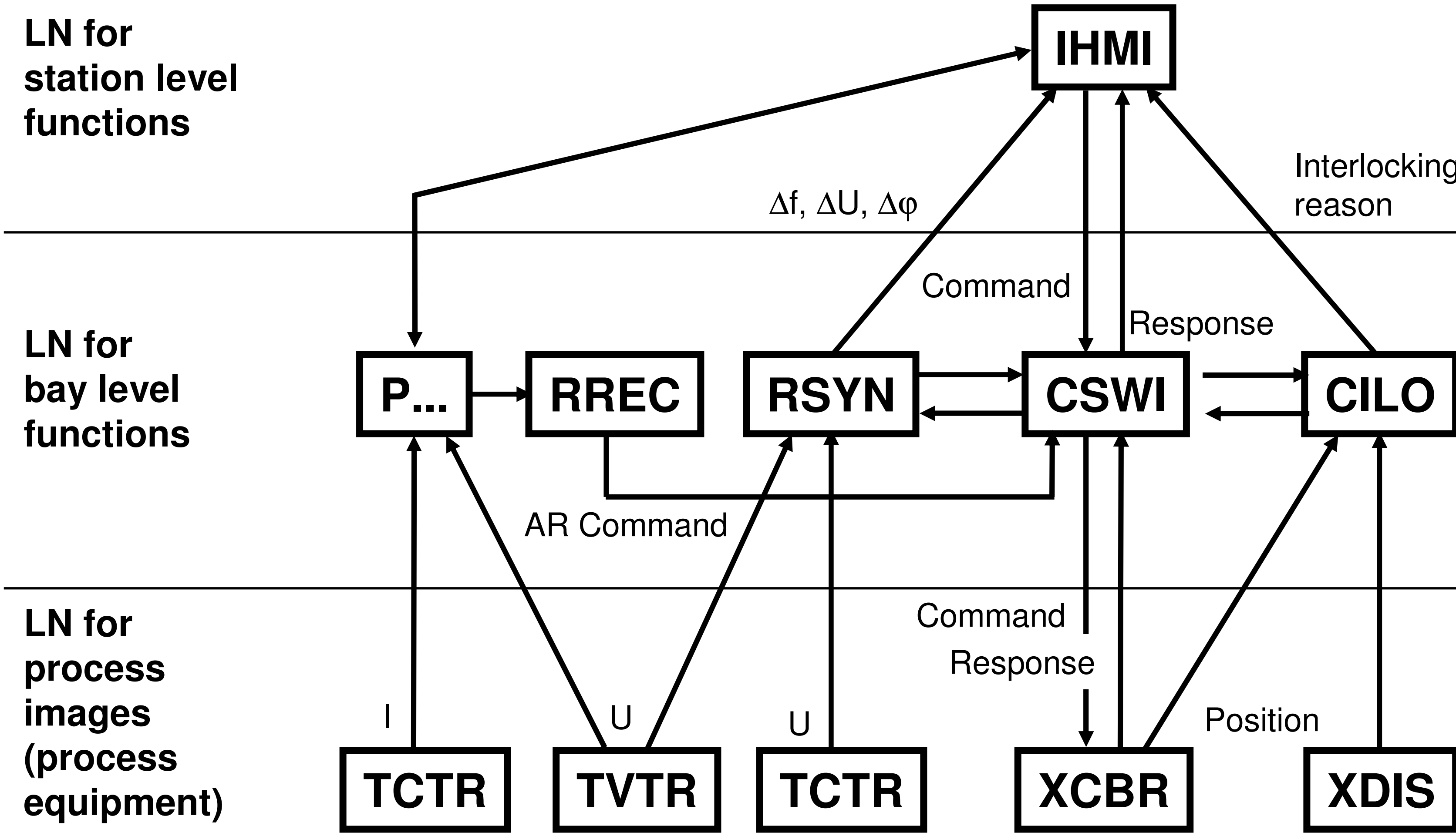


Class (part 7)

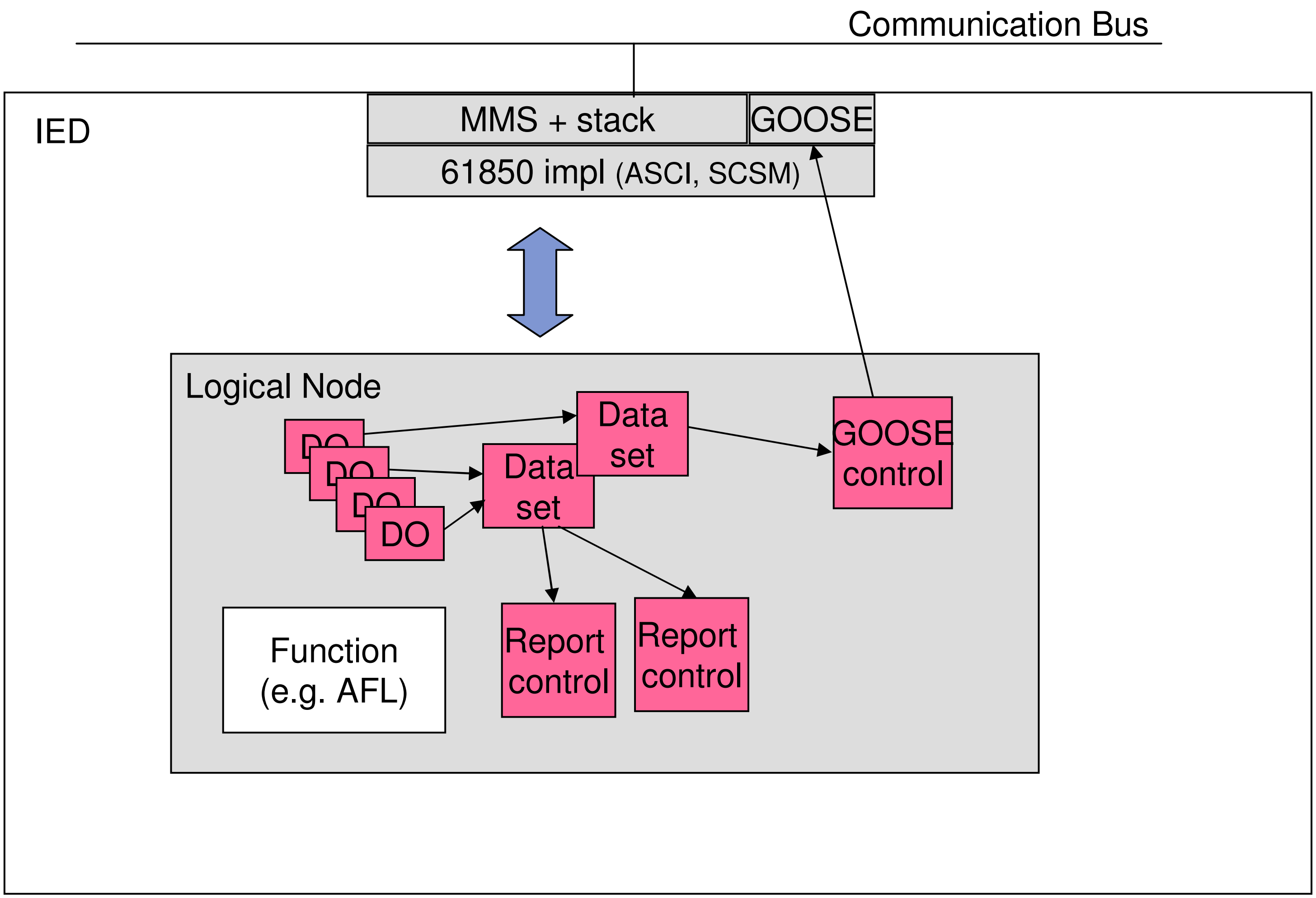
Type (part 6, SCL)

Instance

Examples for Logical Nodes in IEC 61850
control with synchrocheck, auto-reclosure, and interlocking



The Logical Node, content



Back

XCBR - Circuit breaker

This LN is used for modelling switches with short circuit breaking capability. Additional LNs for example SIMS, etc. may be required to complete the logical modelling for the breaker being represented. The closing and opening commands shall be subscribed from CSWI or CPOW if applicable. If no services with real-time capability are available between CSWI or CPOW and XCBR, the opening and closing commands are performed with a GSE-message (see IEC 61850-7-2).

XCBR class				
DATA Class	**Attr. Type**	**Explanation**	**T**	**M/O**
		Common Logical Node Information		
		LN shall inherit all Mandatory Data from Common Logical Node Class CLN		M
Loc	SPS	Local operation (local means without substation automation communication, hardwired direct control)		M
EEHealth	INS	External equipment health		O
EEName	DPL	External equipment name plate		O
OpCnt	INS	Operation counter		M
		Controls		
Pos	DPC	Switch position		M
BlkOpn	SPC	Block opening		M
BlkCls	SPC	Block closing		M
ChaMotEna	SPC	Charger motor enabled		O
		Metered Values		
SumSwARs	BCR	Sum of Switched Amperes, resetable		O
		Status Information		
CBOpCap	INS	Circuit breaker operating capability		M
POWCap	INS	Point On Wave switching capability		O
MaxOpCap	INS	Circuit breaker operating capability when fully charged		O

[Back](#)

CLN - Common Logical Node

The compatible logical node classes defined in this document are specialisations of this Common Logical Node Class.

CLN class				
DATA Class	**Attr. Type**	**Explanation**	**T**	**M/ O**
Mandatory Logical Node Information (Shall be inherited by ALL LN but LPHD)				
Mod	INC	Mode		M
Beh	INS	Behavior		M
Health	INS	Health		M
NamPlt	LPL	Name plate		M
Optional Logical Node Information				
Loc	SPS	Local operation		O
EEHealth	INS	External equipment health		O
EEName	DPL	External equipment name plate		O
OpCntRs	INC	Operation counter resetable		O
OpCnt	INS	Operation counter		O
OpTmh	INS	Operation time		O

T = Transient, M = Mandatory, O = Optional

Logical Nodes: In total 92 divided into 13 groups

Indicator	Logical node groups	Qty
L	System Logical Node	3
P	Protection Functions	28
R	Protection Related Functions	10
C	Supervisory control	5
G	Generic Function References	3
I	Interface and Archiving	4
A	Automatic control	4
M	Metering and Measurement	8
S	Sensors, Monitoring	4
X	Switchgear	2
T	Instrument Transformer	2
Y	Power Transformer	4
Z	Further (power system) equipment	5

- PDIR Directional Comparison
- PDIS Distance
- PSCH Protection scheme
- PTOC Time overcurrent
- PDIF Differential
- more …..

- RDIR Directional element
- RDRE Disturbance recorder function
- RBRF Breaker failure
- RFLO Fault locator
- RREC Autoreclosing
- more…

- CSWI Circuit breaker/switch
- CALH Alarm handling

more …..

- MMXU Measuring (Measurand unit)
- MMTR Metering
- MSQI Sequence and imbalance
- MHAI Harmonics and inter-harmonics
- more …..

- XCBR Circuit breaker
- XSWI Circuit switch

ABB

LN: Time Overcurrent Name: PTOC

PTOC class				
Attribute Name	**Attr. Type**	**Explanation**	**T**	**M/O**
LNName		Shall be inherited from Logical-Node Class (see IEC 61850-7-2)		
Data				
Common Logical Node Information				
		LN shall inherit all mandatory data from Common Logical Node Class		M
OpCntRs	INC	Resetable operation counter		O
Status Information				
Str	ACD	Start		M
Op	ACT	Operate	T	M
TmASt	CSD	Active curve characteristic		O
Settings				
TmACrv	CURVE	Operating Curve Type		O
StrVal	ASG	Start Value		O
TmMult	ASG	Time Dial Multiplier		O
MinOpTmms	ING	Minmum Operate Time		O
MaxOpTmms	ING	Maximum Operate Time		O
OpDlTmms	ING	Operate Delay Time		O
TypRsCrv	ING	Type of Reset Curve		O
RsDlTmms	ING	Reset Delay Time		O
DirMod	ING	Directional Mode		O

T = Transient, M = Mandatory, O = Optional

Example:
The attribute 'Str' (Start indicates the detection of a fault or an unacceptable condition. Str may contain phase and directional information) **is of type 'ACD'** (Directional protection activation information)

Example: Directional protection activation information (ACD)

The Attribute 'Str' is of Attribut Type 'ACD' and is a class with mandatory, optional and conditional information.

Attr. Name	**Attr. Type**	**Value/Value Range**	**M/O/C**
general	BOOLEAN		M
dirGeneral	ENUMERATED	unknown | forward | backward | both	M
phsA	BOOLEAN		GC_2 (1)
dirPhsA	ENUMERATED	unknown | forward | backward	GC_2 (1)
phsB	BOOLEAN		GC_2 (2)
dirPhsB	ENUMERATED	unknown | forward | backward	GC_2 (2)
phsC	BOOLEAN		GC_2 (3)
dirPhsC	ENUMERATED	unknown | forward | backward	GC_2 (3)
neut	BOOLEAN		GC_2 (4)
dirNeut	ENUMERATED	unknown | forward | backward	GC_2 (4)
q	Quality		M
t	TimeStamp		M

GC_2 (n)   All or none of the data attributes belonging to the same group (n) shall be present for a given instance of DATA.

IEC 61850 modeling example

Bay A — Bay Unit

BayA/CSWI

PTOC	(Time Over Current)
RREC	(Autorecloser)
CSWI	(Control – Circuit breaker)
MMXU	(Measurement unit)
CSWI	(Control - Disconnector)
MMTR	(Metering)

IEC 61850 modeling example

BayA/CSWI.Pos

Bay A — Bay Unit

- PTOC — (Time Over Current)
- RREC — (Autorecloser)
- **CSWI** — (Control – Circuit breaker)

Mode	Mode
Beh	Behavior
Health	Health
NamePlt	Name Plate
Loc	Location
OperCnt	Operation Counter
Pos	**Switch position general**
PosA	Switch Position Phase A
PosB	Switch Position Phase B
PosC	Switch Position Phase C
OpOpn	Operation open switch
OpCls	Operation close switch

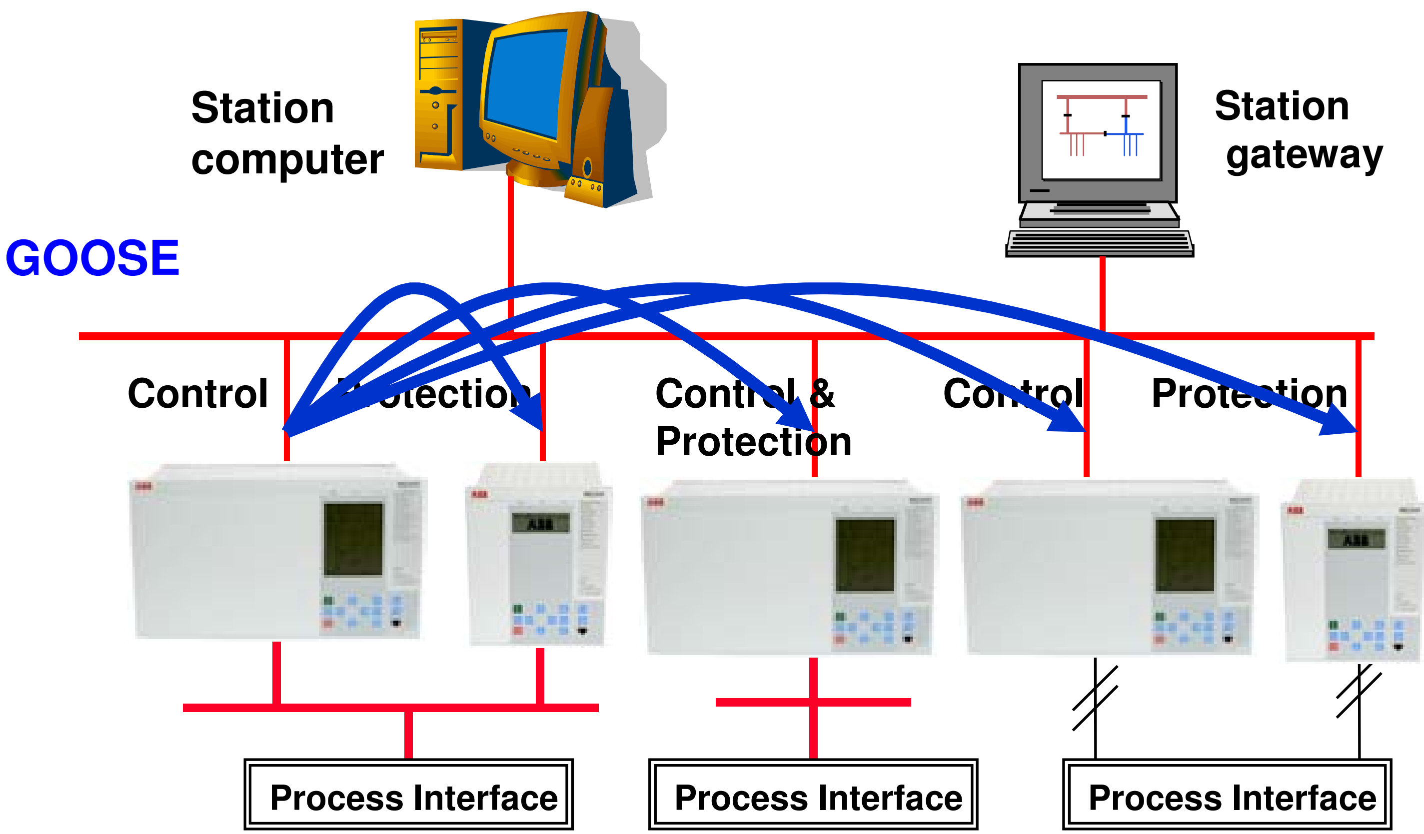
IEC 61850 modeling example

BayA/CSWI.Pos.stVal

- Bay A — Bay Unit
  - PTOC (Time Over Current)
  - RREC (Autorecloser)
  - **CSWI** (Control – Circuit breaker)
    - Mode — Mode
    - Beh — Behavior
    - Health — Health
    - NamePlt — Name Plate
    - Loc — Location
    - OperCnt — Operation Counter
    - **Pos** — **Switch position general**
      - ctVal
      - **stVal**
      - pulseConfig
      - operTim
      - q

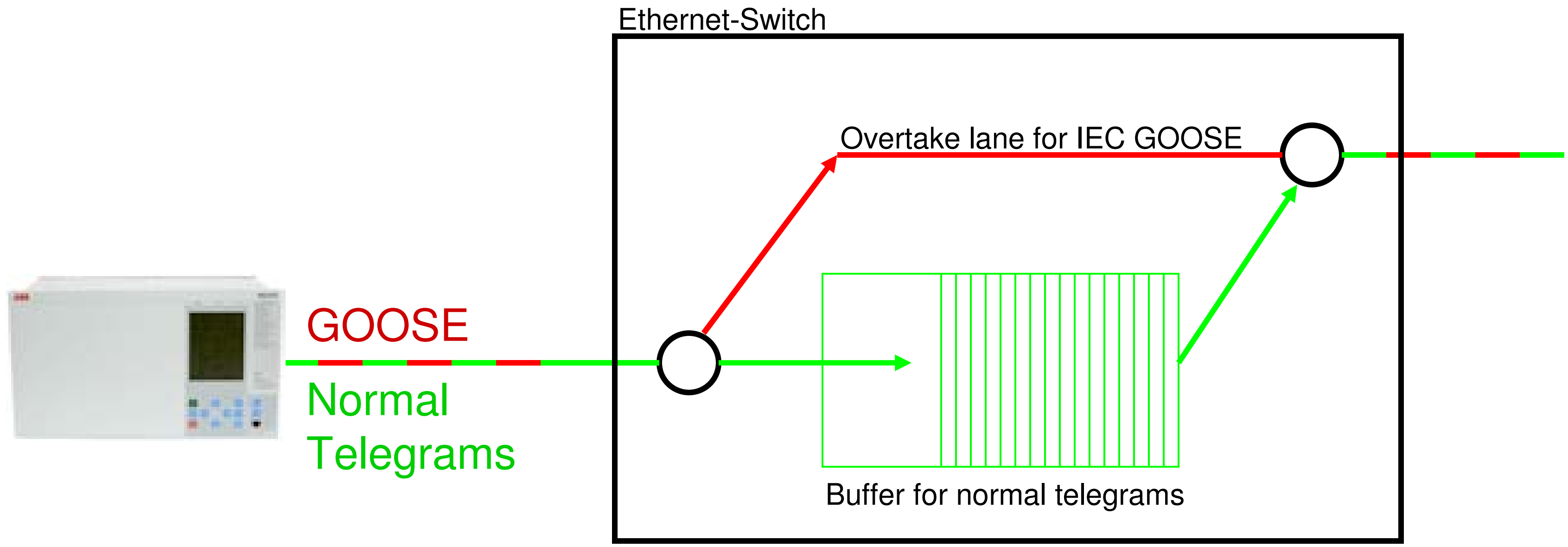
Intermediate-state	(0)
off	(1)
on	(2)
bad-state	(3)

Horizontal (peer-to-peer) communication



GOOSE = Generic Object Oriented System-wide Events

IEC 61850 GOOSE Priority tagging



- IEC 61850 uses standard Ethernet
- IEC 61850 can therefore take advantage from all the options of modern Ethernet

61850-6, SCL

- The language itself is based on XML. For above purpose it contains the following subsections:
  - Substation subsection
    - single line diagram, and its binding to LNs as well as the placement of logical nodes onto IEDs.
      - binding of IEDs to substation parts and substation devices is defined.
  - Communication section
    - communication connections between IEDs in terms of connecting communication links
  - IED section
    - capabilities (configuration) of one or more IEDs, and the binding to logical nodes on other IEDs
  - LNType section
    - defines which data objects are really contained within the logical node instances defined for the IEDs

IEC 61850 – Objectives of the standard

- Introduction
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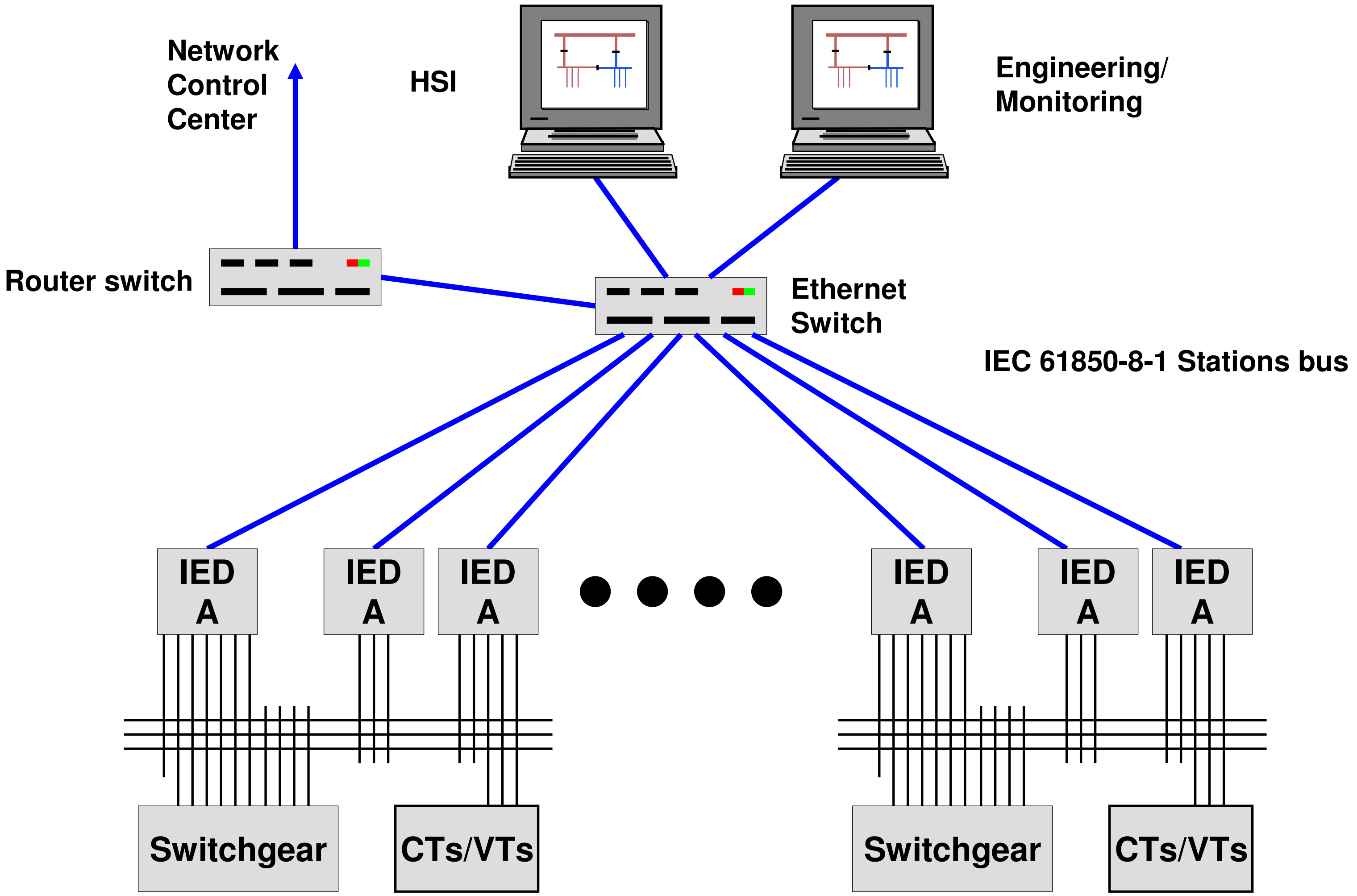
- Conclusions

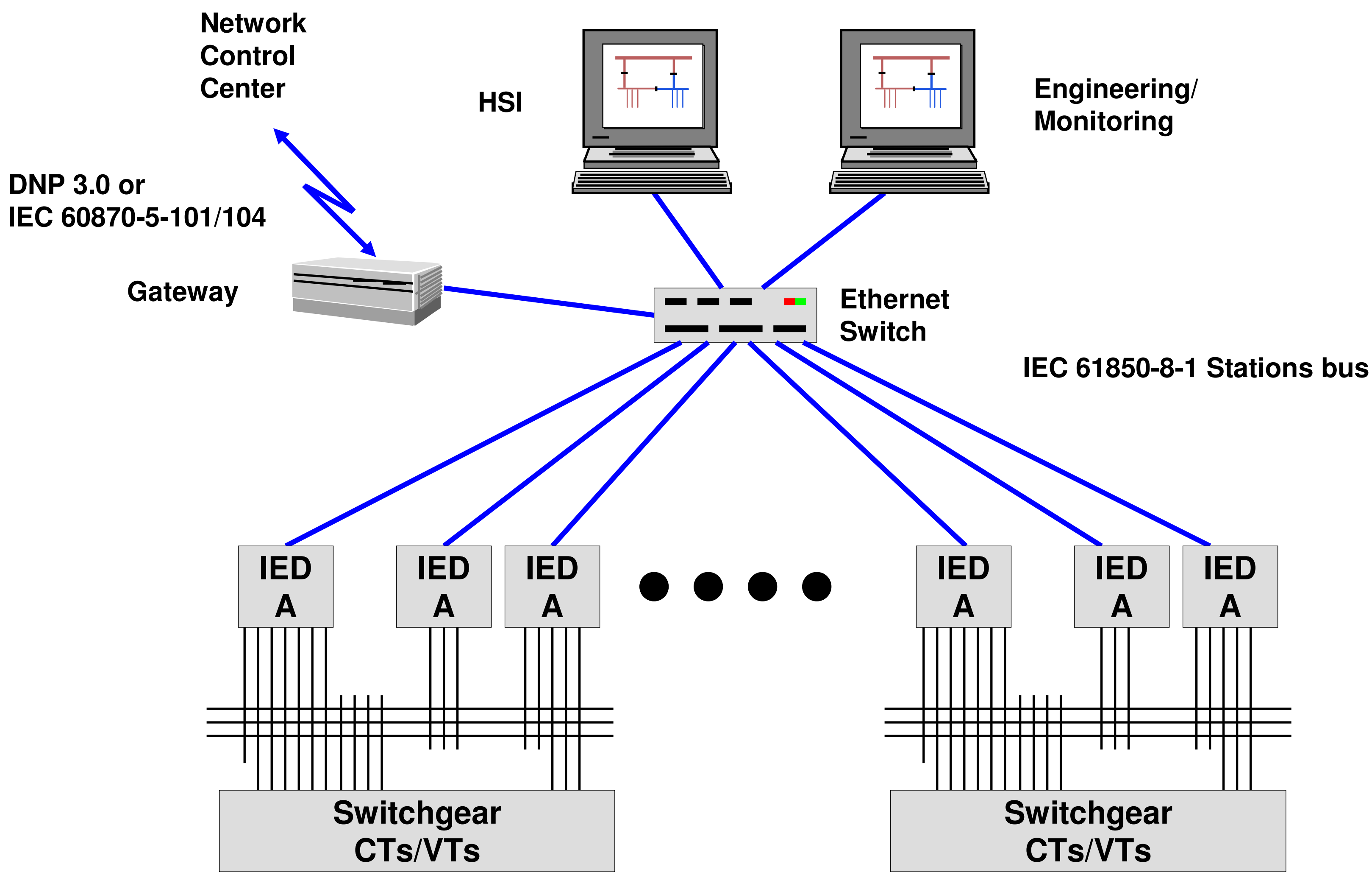
The substation LAN

- IEC 61850 specifies only the interface to the substation LAN
  - The LAN itself is left to the system integrator
- The Ethernet LAN is a subpart of the station and needs engineering, configuration, supervision, and control as any other subparts
  - A network management system is appropriate
- The LAN topology depends on a number of constraints:
  - Operational requirements for the substation
  - Size of the substation
  - Reliability and availability
  - etc.
- The substation LAN as a whole will likely be separated in a station bus and one or more process buses
  - Experience from previous substation communication architectures have shown that this is a sensible approach

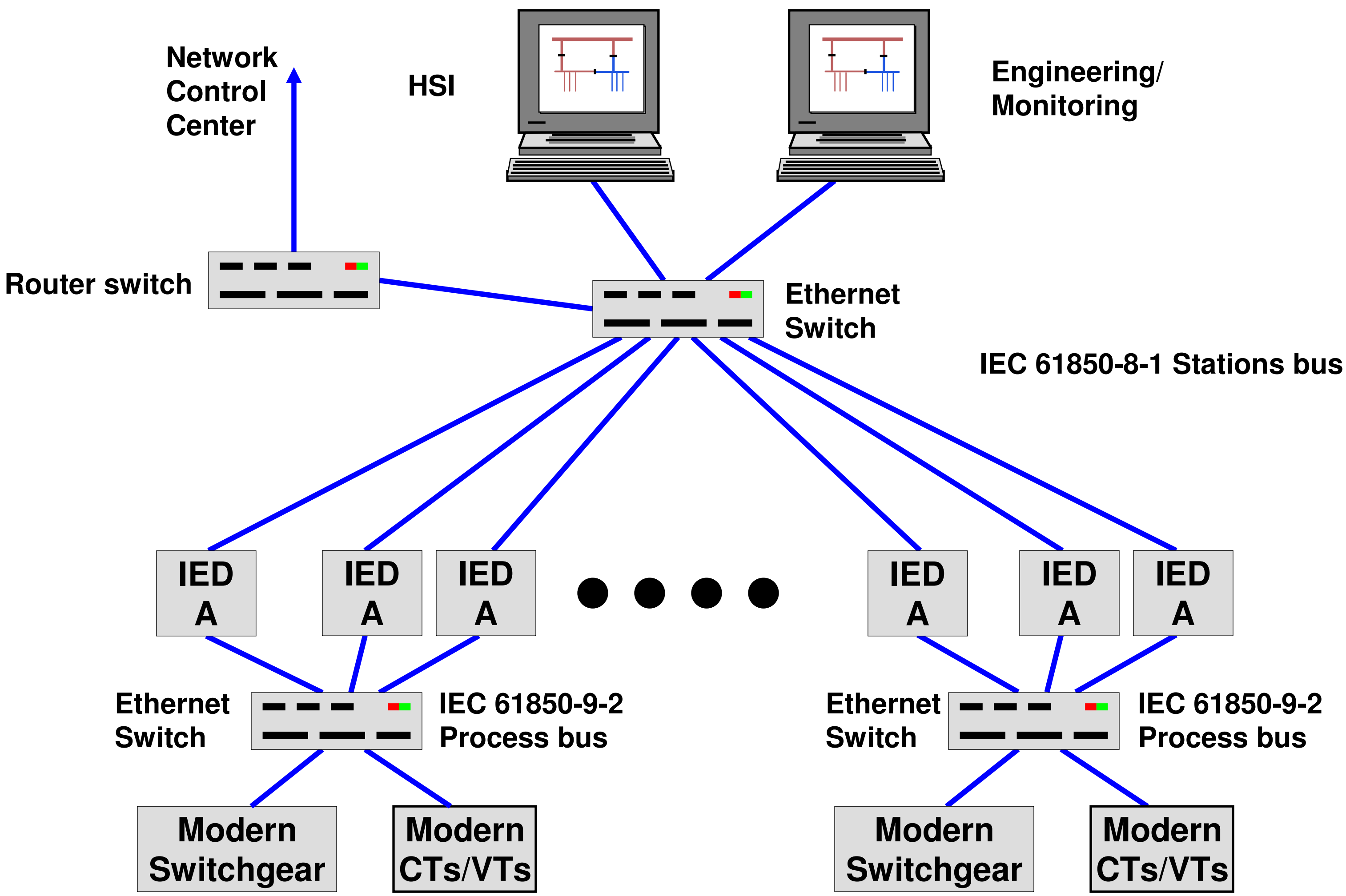
Station bus and conventional process wiring



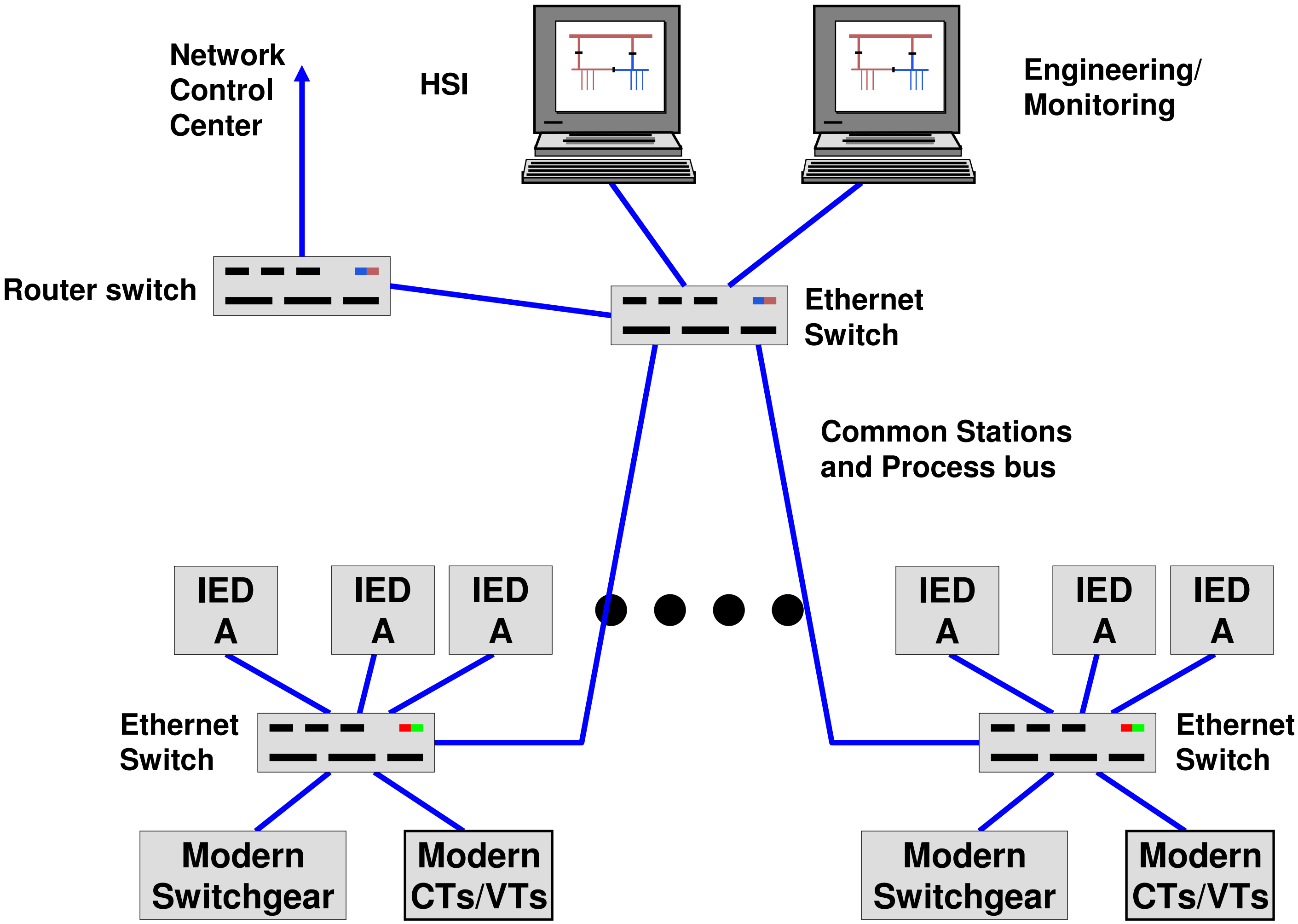
Station bus and conventional process wiring



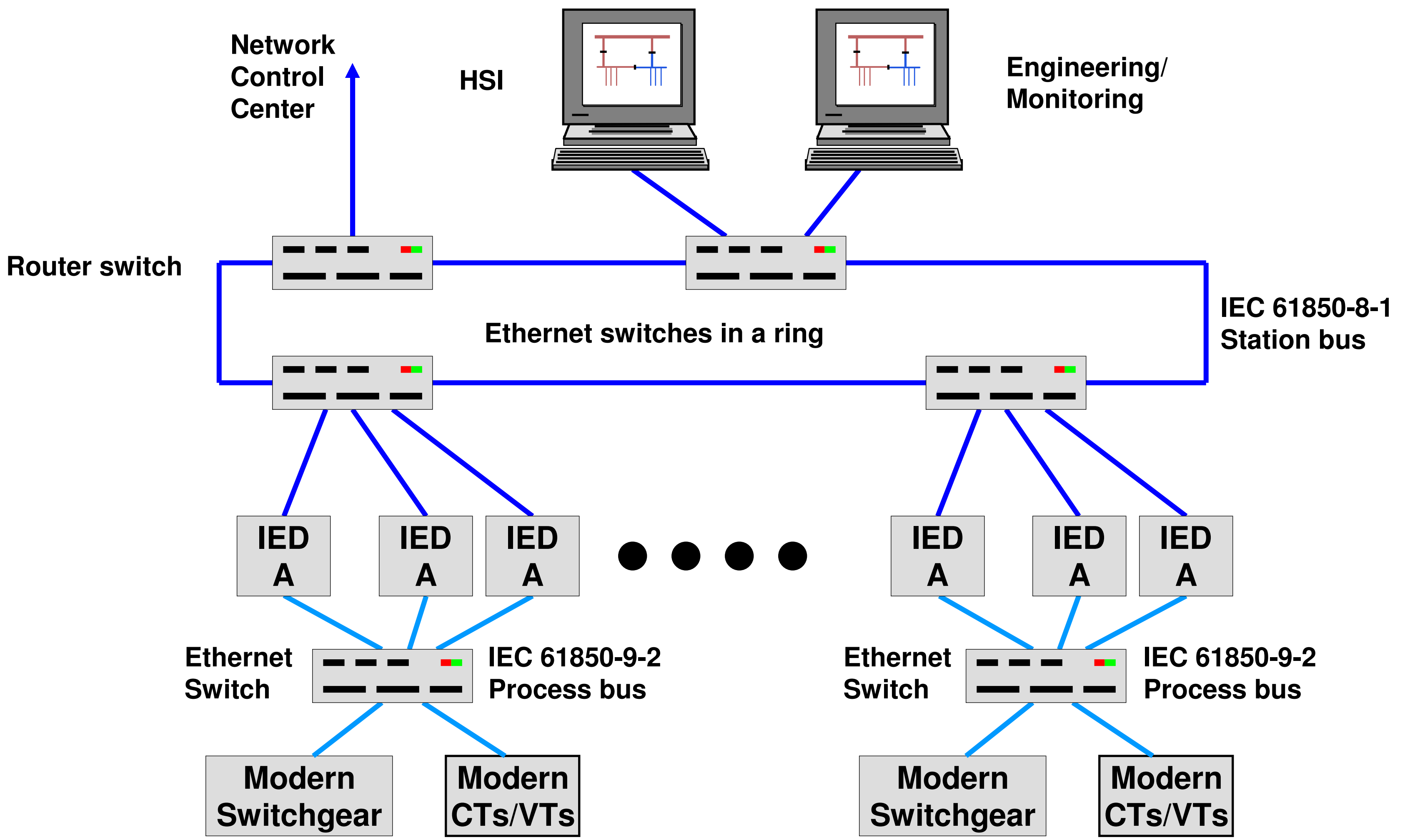
Separate station and process busses



Common station and process bus



Station bus in ring and a separate process bus



Switch for an IEC 61850 network *Example 1*

- Connects IEC 61850 nodes together
  - Multipurpose Ethernet switch
    - Manufactured by OnTime in Norway - www.ontimenet.com
  - Several network topologies supported
  - One T200 RealSwitch on top of the topology
    - Time synchronization switch with integral time server
  - R200 RingSwitch on next levels
    - In principle unlimited number of hierarchical levels
  - Runs on 10/100 Mbit/s
  - Time accuracy better than 0,5 µs regardless of load

- 8 ports whereof max 6 can be optical
  - Different types of connectors available – LC type recommended
  - Full flexibility regarding port combination – TX, SM,MM
  - The port is learning addresses in order to prevent flooding when it begins forwarding traffic

Switch for an IEC 61850 network

Example 1

- Easy configured by means of the free OnTimeConfig tool. Any of the Ethernet ports can be used
  - Remote configuration through network possible
    - IP address
    - Parameters No moving parts or electrolytic capacitors
- User configurable fault contact
- Redundant power input
- High MTBF numbers

- Subnets
  - One IEC 61850 OPC server in MicroSCADA Pro equals to one subnet.
  - Theoretically no limitation, but in practice about 4 subnets
  - Maximum 30 nodes per subnet
  - Nodes on one subnet can be split into several subnets when assigning the IP addresses

ABB

Switch for an IEC 61850 network *Example 2*

RuggedSwitch™ - RS1600F

- Connects IEC 61850 nodes together
  - Multipurpose Ethernet switch
    - Manufactured by RuggedCom Inc in Canada - www.ruggedcom.com
  - Several network topologies supported
  - One RS1600F on top of the topology
    - In principle unlimited number of hierarchical levels
  - Runs on 10/100 Mbit/s

- 16 optical ports
  - Different types of connectors available – LC type recommended
  - Full flexibility regarding port combination – SM, MM
  - The port is learning addresses in order to prevent flooding when it begins forwarding traffic

Switch for an IEC 61850 network *Example 2*

RuggedSwitch™ - RS1600F

- LED indicators for link, activity and speed aid in field troubleshooting
- RuggedSwitch Operating System (ROS) for advanced networking features like:
  - Port configuration
  - Port mirroring
  - Port statistics
  - Port Security
  - Event logging and alarms
- Critical alarm relay
- Redundant power input
- Full duplex operation (no collisions)

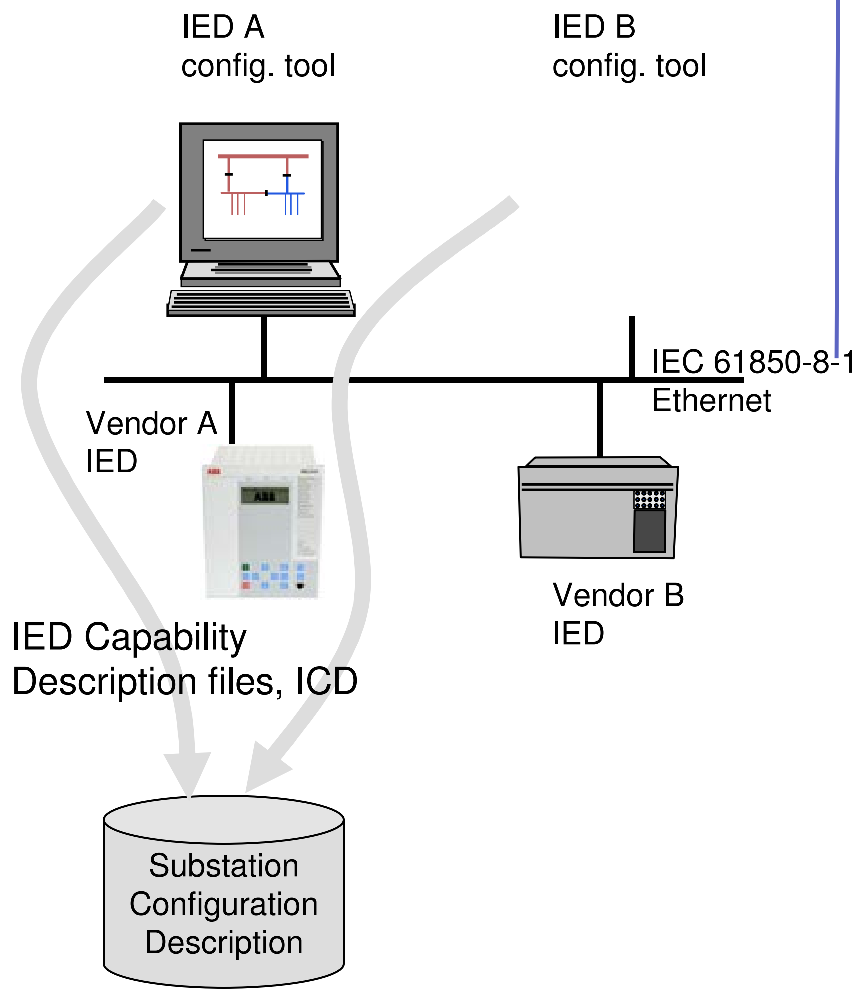
- High reliability
  - Exceeds that of commercial Ethernet switches by having no rotating mechanical parts such as cooling fans
  - by utilizing high-temperature solid-state components.

Engineering and Configuration

- Savings from efficient IED engineering
  - IEDs are engineered using manufacturer specific IED configuration tools
  - Configuration tools translate the IED capabilities and configuration to the SCL (Substation Configuration description Language)
  - SCL enables information exchange between IED configuration tools from different manufacturers
  - SCL secures backwards compatibility between different versions of IEDs and IED configuration tools

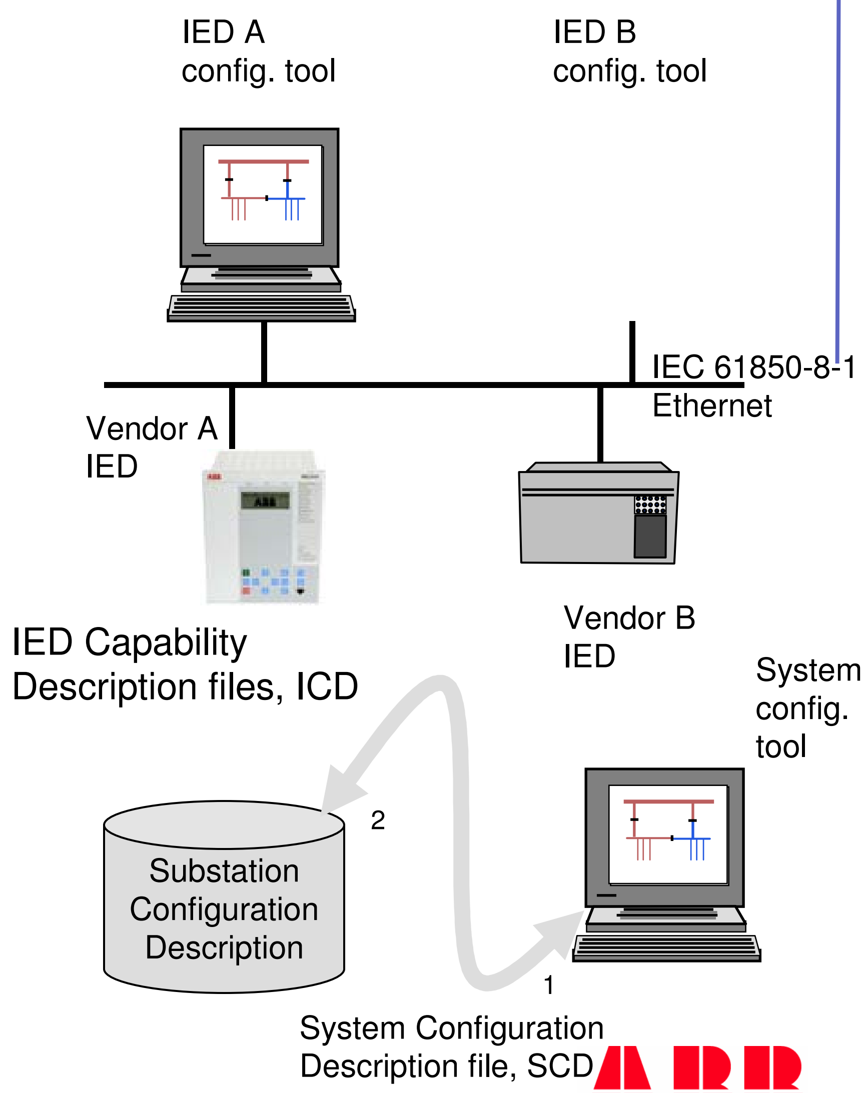
Engineering and Configuration Example 1/3

- Step 1:
  - Select IEDs according to functional requirements
  - Configure IEDs
    - IED specific tool
    - Default **I**ED **C**apability **D**escription file, ICD, as basis
      - For ABB IEDs the default ICD file is part of the **IED Connectivity Package**
  - Create individual ICD file, for the IEDs
  - Download all ICD files into the System Configuration Description database



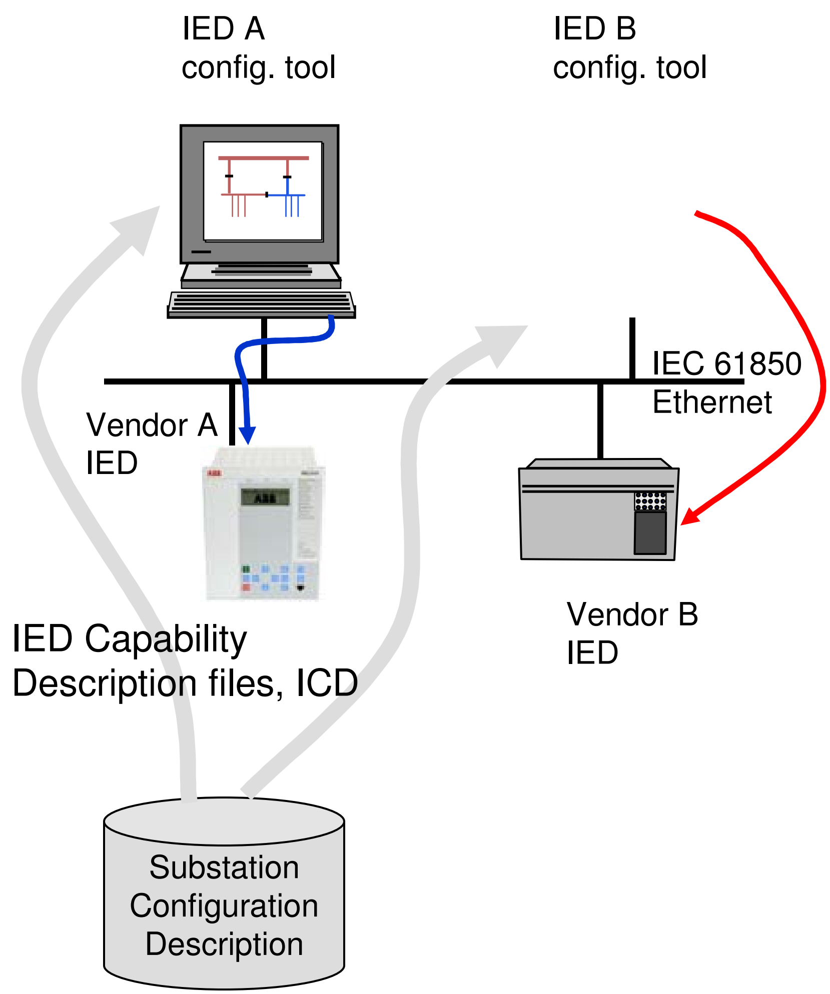
Engineering and Configuration

- Step 2:
  - Upload all ICD files into the System Configuration tool
  - Define cross-references between the IEDs
  - Set System parameters for the IEDs
  - Update the individual ICD files
  - Download all ICD files into the System Configuration Description database and the System Configuration Description file, SCD



Engineering and Configuration — Example 3/3

- Step 3:
  - Upload the ICD and SCD files into the IED specific tool
  - Create the run-time parameter files for the individual IEDs
    - in vendor specific format
    - in a SCL based format as Configured IED Description file
  - Download the run-time files into the individual IEDs
    - MMS services
    - FTP
    - proprietary method



IEC 61850 – Migration and conformance tests

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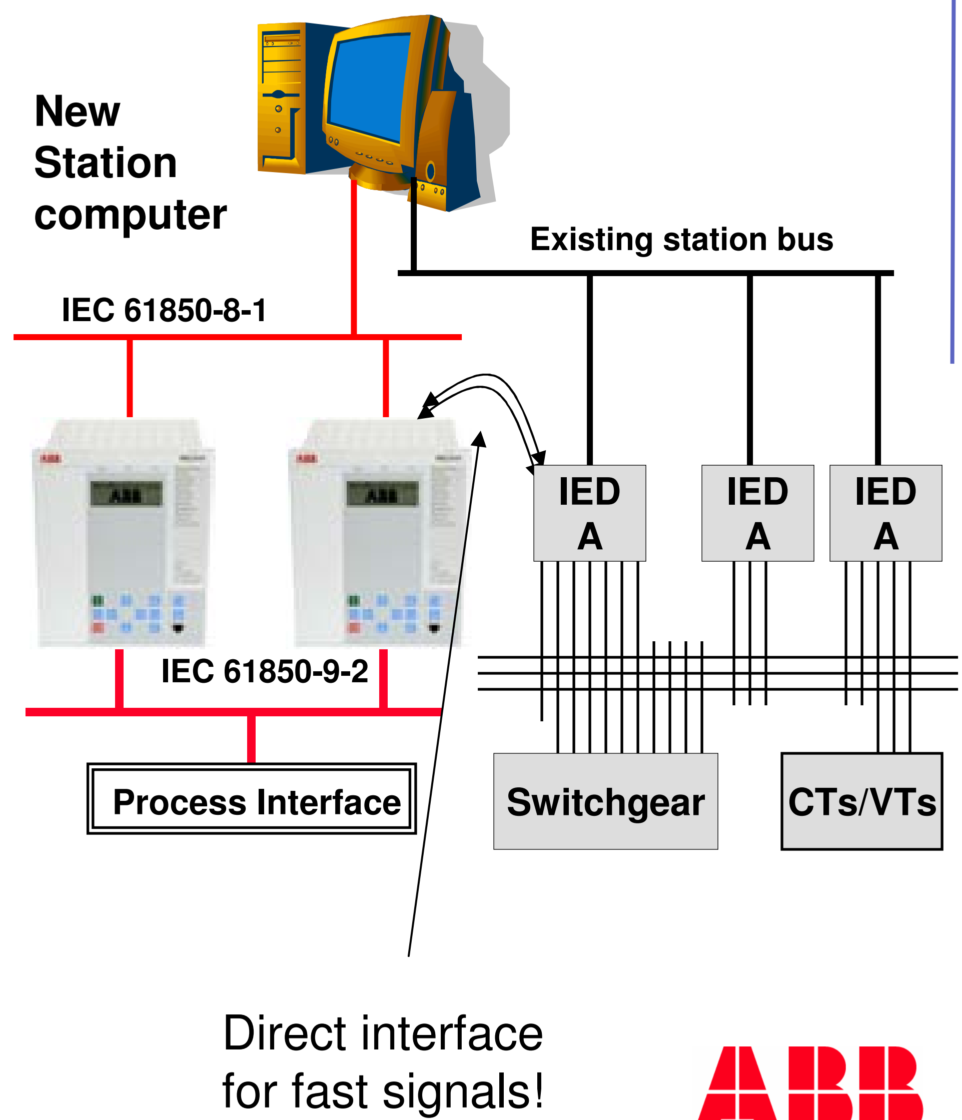
Migration to IEC 61850

- Migration is technically possible as
  - Replacement of station level devices
  - Total or partial replacement of bay level devices
  - Total or partial replacement of process level devices
  - Extension with one or more bays
- Migration may not be profitable
  - Two kinds of maintenance types in mixed installations
  - No functional benefits
- Consider to migrate the total substation!

Migration on station level

- Station computers and gateways will for long be compatible with current station bus protocols/interfaces
- Separation of communication and operator functions will allow for mix of station bus protocols, e.g. IEC 61850-8-1 and LON
  - Fast signalling between the IEC 61850 system and a legacy system can easily be handled using direct wiring (BI /BO) between a (dedicated) IEC compatible control IED and the legacy IED(s). The IEC compatible IED 'GOOSEs' these signal to the rest of the IEC 61850 system.



Migration on bay and process levels

- Replacement of single IED
  - Replace with plug compatible IED, if possible an IEC 61850 compatible one
- Retrofit of bay
  - Select an IEC 61850 compliant set of IEDs, vendors will have IEC 61850 compliant IEDs with interfaces compliant to today's
- Extension with new bay
  - As for retrofit but consider also a full process bus
- Retrofit of primary equipment or transducer/actuator
  - Same as retrofit or new bays

Conformance tests

- The conformance tests include verification of the vendor provided information and tools, as for example
  - The formal SCL description of the IED in the ICD file, IED Configuration Description file
  - The SCD, System Configuration Description, file that describes the system used for the verification of the IED.
- Conformance tests can be performed by the vendor himself or by an independent test organization as KEMA
- Interoperability between products from different vendors guaranteed by
  - Quality Assurance program during development, market introduction, and project execution
  - Conformance tests as type test for the communication capabilities

IEC 61850 – Conclusions

What is not part of IEC 61850?

Competition remains ...

- Product functions are not standardized and not included
- Operator functions and operator interfaces are not standardized and not included
- Products from different vendors are interoperable but not necessarily interchangeable
- **..so it still matters what supplier the customers choose**

IEC 61850 – Benefits and Conclusions

- The standard for substation automation!
- Higher degree of flexibility though interoperability between IEDs from different vendors
- Taking full advantage of future innovations within Substation Automation and communication technologies
- Promises cost reductions from design to operation and maintenance!
- Substation architecture adapted to your requirements
- Gives the opportunity to select ‘Best value for money’
- Embraced by vendors and users equally!

ABB has Developed New IEC61850 Product Range

- IED670 has a common library for protection, control, monitoring and measuring functions
- This library is modeled as logical nodes according to IEC 61850
- All functions are available for all protection- and control devices
  - Full flexibility for example to mix algorithms
- This Library is independent of hardware

ABB IEC 61850 Projects in Transmission Substations

- 380 kV Laufenburg SS for EGL Switzerland **(World first HV IEC 61850 Substation)**
- 400/132kV GIS SS for ADWEA, UAE
- Six 400/220kV GIS/AIS SSs for PGCIL, India
- 400/220/110kV SSs Dobrudja & Varna, NEK, Bulgaria
- 220/132/33kV SS for Sohar Industrial Area, Oman
- Three 220/66/11 kV GIS substations for MEW, Bahrain
- Twenty SA systems 132/11 kV SSs for DEWA, Dubai
- 138kV Soler & Médanos S/Ss for ENELVEN, Venezuela
- Senelec's Hann 90/30kV SS for SENELEC, Senegal
- Osijek-4, 110/20kV SS for HEP, Croatia
- …

IEC 61850 - References / Links

- IEC 61850 Communication Networks and Systems in Substations available for subscribers
- http://www.61850.com
- UCA International Users group
  http://www.ucausersgroup.org

ABB